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# Investigating the effect of pretreatments and different levels of lentil seed flour replacement on the physicochemical and sensory characteristics of gluten-free cake based on rice flour

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ABSTRACT

This study aims to evaluate the effects of pre-treatments such as soaking-peeling, cooking, and roasting lentil seeds on the functional characteristics (water and oil absorption, and emulsification) of lentil flour. The optimal treatment was then selected and replaced with rice flour in gluten-free cake formulation to investigate its effects on functional, physical, qualitative, and sensory properties of the cake. Lentil seed flour was replaced with rice flour at levels of 30%, 50%, and 80%. The examination of different pretreatments revealed that cooked lentil flour exhibited the highest water absorption (2.00%), oil absorption (1.38%), and emulsification capacity (44.60%). Cooked lentil flour was chosen as the optimal treatment and incorporated into the gluten-free cake formulation. Results showed that increasing the amount of lentil flour replacement led to higher density, consistency of the dough, moisture, protein, and a* index of the cakes, while hardness, L* and b* indices decreased. Sensory evaluation results indicated that up to 50% replacement with cooked lentil flour did not significantly alter general acceptance. Therefore, based on the study's findings, it is suggested to replace 50% of rice flour with cooked lentil flour in gluten-free cake formulation.

## 1- Introduction

Cake is one of the important bakery products and its definition varies in different parts of the world; however, cake refers to products prepared by formulations based on wheat flour, sugar, eggs and liquids (such as milk and water) and fat or oil can also be added to their formulation. The amount of liquids added to the cake formulation is such that a dough with a low viscosity is obtained compared to bakery dough. A key difference between cake and bread is that cakes are mostly baked in a mold, pan or special containers in order to hold and shape the cake dough [1]. Rice flour-based cakes are one of foods with high-starch that are traditionally consumed in Asian countries and have been developing in Western societies since the early 1980s due to their ingredients, lower calories and also containing gluten-free proteins [2, 3]. Celiac disease is an autoimmune intestinal disease caused by damage to the villi of the small intestine due to exposure to gluten. Studies have shown that more than 0.5% of people living in Asia suffer from this disease. Celiac disease has a diverse clinical spectrum, which sometimes makes it difficult to diagnose. While its classic symptoms include abdominal symptoms such as chronic diarrhea, pain, vomiting, bloating, and constipation. In recent years the non-classical and asymptomatic forms of the disease have been identified. These unusual symptoms include poor growth, short stature, anemia, arthritis, and osteoporosis [4]. In general, the treatment of celiac disease is based solely on the permanent elimination of gluten-containing grains (wheat, barley, rye, and oats) from the diet and use of gluten-free foods throughout the life of the patient [5]. A significant part of wheat protein is gluten, which limits its use for the production of gluten-free products for people with celiac disease. Reducing the amount of wheat gluten by breeding methods or removing gluten from wheat flour can be a solution for its use in gluten-free products, but this reduces the quality of products produced from it [6]. According to lack of gluten in gluten-free flours, substances can be used to imitate the properties of gluten or to strengthen it in order to improve the quantity and quality of this category of products. Replacing gluten with these compounds is the main technological problem. Food hydrocolloids or gums are hydrophilic biopolymers with high molecular weight used as functional ingredients in the food industry, and numerous studies indicate the use of these compounds in the baking industry. Hydrocolloids are considered a suitable alternative to gluten in the production of gluten-free baked goods due to their structural properties and ability to bind with water. Using other grains to produce gluten-free biscuits, cakes, and cookies is another solution that has been proposed. However, using other grains to produce such products can also affect the properties and quality of the product [7]. Therefore, some studies have addressed the improvement of the quality of such products by supplementing them with various compounds [8]. Edible legumes, which are the main source of plant proteins in human nutrition, are a suitable alternative to animal proteins due to their cheapness, easy availability, and high nutritional value. Among plant sources, legumes have a special place in the human diet, because they contain two to three times more protein than grains [9]. Legumes are the best sources of protein,



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dietary fiber, and minerals, while they do not contain gluten [10, 11]. Lentil is one of the most important cryophilic products that are usually cultivated in Iran under dry conditions. With about 28% protein, this plant is a major bean in developing countries and is considered a supplement to cereals and a suitable source of protein and amino acids in the diet of the people of these countries [12]. A wide range of processing techniques such as soaking, autoclaving, peeling, boiling, cooking, sprouting, fermentation and ultrasound are used in an attempt to increase the usefulness of legumes for purposes such as increasing the nutritional value and digestibility. Soaking, sprouting, fermentation and autoclaving are primary processes that affect the reduction or elimination of anti-nutritional factors. In addition, controlled heat treatment ensures that the carbohydrates in the legumes are partially gelatinized and increases digestibility, inactivates anti-nutritional factors, and increases the availability of essential amino acids in the legumes [13, 14]. Artash (2021) investigated the improvement of cake quality using red kidney beans using different traditional processing methods. This study aimed to evaluate the effects of adding red kidney bean flour to soaked, peeled, baked, and roasted alternatives to wheat flour on the functional, physical, qualitative, and sensory properties of the cake and compared to the control cake. The results indicated that traditional processing methods affect the functional properties of red kidney bean flour, as the emulsifying capacity and foaming capacity increased but the oil holding capacity decreased. The addition of red kidney bean flour increased ash and protein content and decreased carbohydrate, fat, and hardness of the cakes [15]. Jeong et al. (2021) also used different levels of cereal flour in cakes and their reports showed a positive effect of these ingredients on the physicochemical properties of the cake [16]. The aim of this research was to produce gluten-free cakes with desirable qualitative and nutritional properties for celiac patients using lentil flour (to improve its functional properties).

## 2- Materials and Methods

### 2-1- Materials

For this research, lentil seeds were purchased from the local market of Tabriz city and rice flour was purchased from Golha Food and Agricultural Industries Complex (Tehran).

### 2-2- Pretreatments of lentil seeds

In this study, soaking and peeling, baking and roasting pretreatments were applied to lentil seeds. For soaking and peeling pretreatment: 100 g of lentil seeds were soaked in 500 ml of distilled water at 25°C for 24 hours, the soaked water was removed and the seeds were peeled by hand and then dried at 50°C for 24 hours in an electric oven (Memmert, Germany). For cooking pretreatment: 100 g of lentil seeds were cooked in boiling water and 500 ml of distilled water for one hour and then dried in a hot air oven at 50 °C for 24 hours. For roasting pretreatment: 100 g of lentil seeds were roasted at 160 °C with continuous stirring for 15 minutes. Then, all the treated lentil seeds obtained from the above three methods were ground and sieved (<500 µm) in a laboratory hammer mill [17-18].

### 2-3- Examination of the functional properties of pretreated flour

#### 2-3-1- Water holding capacity (WHC) and oil holding capacity (OHC)

To measure the water and oil holding capacity, 0.1 mg of the sample was mixed with 1 ml of distilled water or oil. Then, it was stirred for 30 minutes at room





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temperature and the samples were centrifuged at 6000 g for 30 minutes (Thermo, Japan). After the supernatant was removed, the tubes were placed in an oven at 50°C for 25 minutes at a 45° angle to remove the surface-adsorbed water. Using the weight difference, the percentage of water or oil holding capacity was calculated based on grams of water or oil absorbed per gram of sample [19- 20].

**2-3-2- Emulsifying capacity (EC)**

The solution obtained from lentil flour - distilled water (in a ratio of 1:10 w/w) was centrifuged at 4000 rpm for 20 minutes. Equal volumes of supernatant and sunflower oil were mixed and homogenized in a blender at low speed for 5 minutes. The homogenized mixture was transferred to a measuring cylinder. The emulsifying capacity was expressed as a percentage of the volume of the emulsified layer and the height of the total cylinder content [21] .

## 2-4- Preparation of gluten-free cake samples

At first, in order to prepare the cake batter, oil, powdered sugar and eggs were mixed using an electric mixer at a speed of 128 rpm for 6 minutes to create a cream containing air bubbles. Then water and invert syrup were added to it and the mixing process was continued for 4 minutes. In the next step, baking powder and vanilla were added to the rice flour (containing different percentages of lentil flour) and the resulting mixture was gradually added to the cream. Finally, using a cloth funnel, 50 grams of the prepared batter was poured into special cake papers placed in the molds. Then, baking was performed in a laboratory oven with hot air at 170°C for 20 minutes. After cooling, each of the samples was packaged in polyethylene bags and stored at room temperature for the purpose of evaluating the quantitative and qualitative properties [22]. The treatments used in this study to prepare gluten-free cake samples are given in Table 1.

Table 1- The treatments used in this study

| Abbreviations | Types of treatments |
|---|---|
| Control | Gluten-free cake made with rice flour |
| 70R30L | Gluten-free cake prepared with a ratio of 70: 30 rice flour: lentil flour |
| 50R50L | Gluten-free cake prepared with a ratio of 50: 50 rice flour: lentil flour |
| 20R80L | Gluten-free cake prepared with a ratio of 20: 80 rice flour: lentil flour |



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## 2-5- Determination of cake dough properties

### 2-5-1- Determination of dough density

Immediately after cake dough preparation, the volume of 30 g of the sample was determined using a graduated cylinder and the dough density was calculated by dividing the weight by the dough volume [23].

### 2-5-2- Determination of dough consistency

To measure the consistency of cake dough, the dough was poured into a funnel with a wide inner diameter. The funnel was completely filled with dough, then the weight of the dough discharged from the funnel was measured over a period of 15 seconds and the dough consistency was reported in grams per second [23]. Larger numbers recorded indicate lower dough consistency.

## 2-6- Determination of Physicochemical Properties of Gluten-Free Cake Samples

### 2-6-1- Measurement of Moisture Content

The moisture content of gluten-free cake samples was determined using the AACC 44-15A method and an electric oven [24].

### 2-6- 2- Measurement of Protein Content

The protein content of the samples was measured using the AACC 46-12 method. For this purpose, one gram of cake samples was weighed in a special digestion vessel and 25 ml of 98% sulfuric acid was added to digest the sample and complete digestion of the sample was continued until it reached a clear green color. After complete digestion, nitrogen distillation was performed, for this purpose, 250-300 ml of water and 50 ml of NaOH were added to the digested solution along with glass beads to prevent explosion. An Erlenmeyer flask containing 50 ml of boric acid and a few drops of methyl red reagent was placed at the end of the distillation apparatus in such a way that the end of the distillation apparatus was completely immersed in the acid, and distillation was performed until a minimum volume of 250 ml was reached. The resulting solution was titrated using 0.1 N sulfuric acid until it reached a pink color and the total protein percentage was calculated from equation 1 [24].

$$(1)\ \text{Protein \% Amount} = \frac{(\text{acid consumption ml} \times \text{sulfuric acid normality} \times 1.4007 \times 6.25)}{(\text{sample weight})} \times 100$$

### 2-6-3- Determination of the volume of production samples

To measure the volume, the AACC 05-10 rapeseed displacement method was used. In this method, rapeseed was poured into a metal container up to the mark line and its volume was noted. Then, each of the gluten-free cake samples was placed in the empty container and rapeseed was poured into it at a uniform speed until it was filled to the mark line. The remaining grains, which indicate the volume difference, were poured into a graduated cylinder and the volume was obtained in milliliters [24].

### 2-6-4- Measurement of the color indices of the samples

To measure the color of the gluten-free cake samples, a digital photography method was used. In this way, the cake samples, which were cut crosswise with a thickness of 3 cm, were placed in a Hunterlab simulator with a white wall (60×50×50) in which two special fluorescent lamps with white light were placed inside and there was a completely uniform light distribution. The photography was done by a digital camera in a perpendicular position to the sample (with a distance of 30 cm). The obtained



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images were transferred to Photoshop software (Adobe Photoshop CC2018) and their color components were calculated, where (L*) is from black (0) to white (100), (a*) is from green (negative values to -120) to red (positive values +120), and b* is from blue (negative values) to yellow (positive values) [25].

**2-6-5- Examination of texture firmness**

Texture properties were performed in the form of texture profile analysis test on the core of gluten-free cake samples. To perform the texture profile analysis test, a texture measuring device and a cylindrical probe were used. After cutting the cake samples to dimensions of 20×20×20 mm, they were compressed to 50% of the initial height, and then the firmness of the cake core was evaluated in the first days after production [26].

**2-6-6- Sensory evaluation of the produced samples**

To determine the general acceptability of the gluten-free cake samples, a 5-point hedonic method was used. Thus, the cake samples were evaluated on the first day of baking by a number of trained sensory evaluators (10 people). To perform this test, water was used between the tests of different treatments to better understand the sensory properties. In this test, the number (1) indicates the lowest score and the number (5) indicates the highest score [22].

## 2-7-Statistical analysis

In this study, firstly, the effect of different pretreatments (soaking and peeling, cooking and roasting) on the functional properties of lentil seeds was investigated in a completely randomized design with three replications. Secondly, the optimal lentil flour selected in the first phase of the research was investigated as an independent variable at three levels of 30, 50 and 80% in gluten-free cake formulation as a substitute for rice flour. Analysis of variance and comparison of means were performed using ANOVA table and Duncan test using SAS version 9.4 software, respectively. Graphs were drawn using Excel version 2019 software.

# 3- Results and discussion

## 3-1- Water holding capacity

The results related to water holding of different pretreated lentil flour samples are given in Table 2. Based on the results, the type of pretreatment had a significant effect on the water holding parameter of lentil flour samples. The highest measured water holding value with an average of 2% was related to cooked lentil flour and the lowest measured value with an average of 1.58% was related to soaked and peeled lentil flour samples. It seems that the removal of fiber from the structure of lentil grains during the soaking and peeling processes has caused a decrease in the water holding capacity of the samples. One of the important properties of fiber is its water retention capacity. Also, based on the results obtained, the application of thermal processing has caused an increase in the water holding capacity of the samples. By applying thermal processes (wet and dry), oligomeric proteins are decomposed into smaller units and these smaller units have a greater water holding capacity than oligomeric proteins. Similar results were observed by Vani et al. (2017) regarding the increase in the water holding capacity of sweet chestnuts during the frying and microwave roasting process [27]. In another study, Jogihali et al. (2017) increased the water holding capacity of chickpeas during the roasting process with microwave [28].

**Table 2-The effect of the type of pretreatment on the measured properties of lentil flour**

| Properties | Soaked and peeled | Cooked | Roasted |
|---|---|---|---|
| %WHC | 1.58±0.03[c] | 2.00±0.13[a] | 1.71±0.04[b] |
| %OHC | 1.10±0.01[b] | 1.38±0.02[a] | 1.35±0.06[a] |
| %EC | 37.30±0.25[b] | 44.60±0.21[a] | 44.42±0.16[a] |

Different lowercase letters within a row indicate significant differences in %5 level

## 3- 2-Oil holding capacity

The results related to the oil holding capacity of lentil flour samples treated with different processes are given in Table 2. Based on the results obtained, the type of pretreatment had a significant effect on the oil holding capacity parameter of lentil flour samples. The highest value of the measured oil holding capacity was related to cooked lentil flour, which did not have a statistically significant difference with the roasted sample ($p<0.05$), and the lowest measured oil holding capacity was related to the soaked and peeled lentil flour sample. Previous studies have also reported that thermal processes increase the water holding capacity values in sweet chestnut [27] and green grass pea, nightingale beans, lentils and chickpeas [29]. Also, in a study conducted by Ertas (2021) on the effect of soaking and peeling pretreatments, cooking and roasting on the water holding capacity of red kidney beans, similar results were obtained. This researcher attributed the increase in oil holding capacity to structural changes in proteins and carbohydrates of flours due to heat, which helped create pores and empty spaces in the flour structure, and these spaces can absorb oil more effectively [15].

## 3-3- Emulsifying capacity

Table 2 showed that the type of pretreatment had a significant effect on the emulsifying capacity parameter of lentil flour samples. The highest measured emulsifying capacity was related to cooked lentil flour, which had no statistically significant difference with the roasted sample ($p<0.05$), and the lowest emulsifying capacity was related to the soaked and peeled lentil flour sample. Factors that affect the emulsifying ability of proteins include solubility, pH, deformation, and concentration. These factors can directly change the emulsifying properties of proteins. Proteins must be dissolved in a liquid medium to form stable emulsions. More soluble proteins are able to form better emulsions because they can be evenly dispersed in the liquid phase. The pH of the medium also affects the emulsifying ability of proteins. Changes in pH can cause protein deformation and affect their emulsification properties. Heat treatments can open the structure of proteins and break down oligomeric proteins into smaller units. These changes can lead to improved solubility and emulsification properties of proteins [30]. Protein concentration also affects their emulsification ability. Higher protein concentrations can lead to the formation of more stable emulsions. In a study conducted by Okaka and Potter, it was shown that heat treatments can improve solubility and emulsion properties by breaking down large proteins into smaller units. Also, Goleta et al. (2019) reported that removing the skin can increase the emulsification capacity of chickpea and


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fava bean proteins compared to raw samples. Therefore, solubility, pH, conformation and concentration of proteins are all known to be key factors in the emulsification ability of proteins and each of them can somehow affect the quality and stability of emulsions [31].

## 3-4- Cake dough density

The results of the study of changes in dough density as a result of replacing rice flour with cooked lentil flour, which are given in Table 3, indicated that the dough density increased with increasing the percentage of lentil flour in the formulation of the produced cakes. The results obtained in this study are consistent with the results reported by Gomez et al. (2008). These researchers reported that the use of fiber increases the density of the dough and this increase depends on the amount of powder added [32]. Lu et al. (2010) found that the increase in dough density with increasing replacement percentage can be attributed to the increase in fiber in bran, so by increasing the water holding capacity of bran, the density of cake dough increases [33]. Ronda et al. (2011) showed that high consistency and density cause less air to be retained in the dough [34]. Majzoubi et al. (2013) reported that increasing the amount of bran in cake dough increases dough density [35]. Also, Majzoubi et al. (2015) reported an increase in cake dough density by using oat fiber, which may be due to the trapping of fewer air bubbles in the dough [36].

## 3-5- Dough consistency

Table 3 showed that replacing cooked lentil flour with rice flour caused significant changes in dough consistency. The lowest dough consistency was found in the control sample and the highest in the sample containing 80% cooked lentil flour. In other words, the dough consistency increased with the increase in cooked lentil flour in the formulation of the produced cakes. The high protein and fiber content in cooked lentil flour and the large number of hydroxyl groups in the fiber structure react with water molecules through hydrogen bonds and absorb water in the dough formulation, which increases the dough consistency [37]. Other researchers also observed an increase in the consistency index and a decrease in the dough flow index with an increase in the percentage of replacement of flours containing high fiber content, and introduced the water retention capacity resulting from the increase in fiber content as the main reason for this [33-38].

**Table 3- The effect of lentil flour percentage on some properties of cake Batter**

| Properties | Control | 70R30L | 50R50L | 20R80L |
|---|---|---|---|---|
| Batter density(g/cm$^3$) | 0.924±0.003$^c$ | 0.950±0.008$^b$ | 0.960 ±0.007$^b$ | 0.994 ±0.007$^a$ |
| Batter consistency (N.S) | 0.41±0.02$^b$ | 0.42±0.02$^b$ | 0.46±0.03$^a$ | 0.48±0.01$^a$ |

Different lowercase letters within a row indicate significant differences in %5 level

## 3-6- Moisture content of produced cakes

Table 4 showed that with increasing the percentage of lentil flour in the formulation of produced cakes, the moisture content of the produced samples increased. This increase can be attributed to the high fiber and protein content of lentil flour, which have the ability to retain more water.





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Another reason for this can be attributed to the decomposition of proteins during the thermal process and the production of peptides with greater water holding capacity as well as hydrophilic amino acids [39- 40]. This increase in moisture can lead to improved texture of cakes and increased freshness. However, it should be noted that increased moisture may have effects on other cake properties such as taste, texture, and shelf life, which require further investigation. Artash et al. (2021) reported an increase in the moisture content of cake samples by investigating the effect of adding bean flour to gluten-free cake formulation [15].

## 3-7- Protein content of the produced samples

Table 4 showed that the protein content of the samples increased with increasing percentage of flour in the cake formulation. Lentil flour, due to its high protein content, can be used as a nutritious alternative to rice flour in gluten-free products. Rice flour is mostly known for its high starch content and usually has less protein than other flours. The low protein content in gluten-free cakes based on rice flour can lead to a decrease in the nutritional value of the final product. In addition to high protein, lentil flour also contains essential amino acids, which adds to the nutritional value of the cake [41-42]. Partial replacement of rice flour with lentil flour improves the nutritional properties of the cake and can be used as an effective solution to increase the protein content in gluten-free products. Increasing the protein content of gluten-free products by adding ingredients such as buckwheat [43] and chia [44] has also been reported.

**Table 4-The effect of lentil flour percentage on some properties of cake**

| Characteristics | Control | 70R30L | 50R50L | 20R80L |
|---|---|---|---|---|
| Moisture content (%) | 17.90±0.30$^{c}$ | 18.50±0.26$^{b}$ | 18.83 ±0.37$^{b}$ | 20.36 ±0.25$^{a}$ |
| Protein content (%) | 6.12±0.08$^{c}$ | 6.94±0.15$^{b}$ | 7.15±0.05$^{b}$ | 7.73±0.14$^{a}$ |
| Volum (cm$^3$) | 105.60±0.69$^{c}$ | 111.00±1.51$^{b}$ | 115.30±0.74$^{a}$ | 110.31±1.12$^{b}$ |
| Hardness (N) | 5.18±0.58$^{a}$ | 3.21±0.38$^{b}$ | 2.02±0.31$^{c}$ | 1.97±0.38$^{c}$ |

Different lowercase letters within a row indicate significant differences in %5 level

## 3-8- Volume of gluten-free cake samples

The results of the research showed that a good cake dough should have a suitable viscosity and consistency to prevent the air bubbles introduced into the dough during the mixing process and the carbon dioxide gas produced from the baking powder used in the formulation from rising to the surface and escaping in the early stages of baking. Also, the cake should be formed in such a way that the air bubbles have enough time to develop properly and expand through the carbon dioxide gas and water vapor, resulting from the formulation liquids. Therefore, the resulting cake will have a very porous and desirable structure [45]. According to Table 4, the results of the comparison of volume changes confirmed the existence of significant changes among the experimental treatments ($P<0.05$). The volume values were in the range of 105.30-115.60 cm3, with the lowest value with an average of 105.36 cm3 corresponding to the control treatment, while the highest value of this index was related to the treatment containing 50% cooked lentil flour with an average of 115.30 cm3. The cake volume indicates the amount of carbon dioxide and ammonia gas produced as a result of the addition of chemical bulking agents used in the dough formula and the range of their changes in the cake core during baking. The moisture-absorbing compounds and additives participating in the cake baking process determine this characteristic. Due to the water-retaining property of the fibers present in cooked lentil flour, the stiffness of the cake dough is reduced and as a result more air bubbles are able to enter the cake and as a result, the cake volume has increased up to the 50% cooked lentil flour treatment [42]. In addition, Gomez et al. (2008) stated that the final volume of cakes does not depend primarily on the initial air content in the cake, but also on the ability of the dough system to retain air during the baking stage. Accordingly, increasing the amount of protein in gluten-free products creates sufficient strength in the product and prevents the rupture of the gas bubble wall during baking with appropriate expansion, leading to an improvement in the volume and specific volume of the produced breads [32]. Artash (2021) reported similar results to this study. These researchers reported an increase in the volume of the produced cakes by investigating the effect of using cooked bean flour in gluten-free cake formulations [15].

## 3-9-Evaluation of the texture firmness of gluten-free cake samples

The firmness index indicates the maximum force in compression or the resistance of the cake core to deformation. Which is considered as one of the important textural properties. This index indicates the stability and firmness of the cake core, and the degree of this firmness and its increase over time is an important factor in assessing its staleness [46]. Most likely, the main cause of the staleness of gluten-free products is the decrease in moisture and its easier migration from the core to the crust, which is a result of the absence of gluten, and the moisture-preserving and moisture-increasing factors in the manufactured product can have a significant effect on delaying staleness [47]. The results of data analysis (Table 4) showed that the use of cooked lentil flour in gluten-free cakes up to a 50% replacement level caused a significant decrease in the firmness values of the cake core samples. The decrease in the firmness of the cake texture due to the addition of cooked lentil flour can have various reasons. Treatments with higher volume showed lower firmness values. As a result, a negative relationship was observed between the volume and firmness of the cake core texture, and too high firmness reflects too low a volume of samples. This is due to the disruption of the fermentation process and the gas-holding network, and consequently the reduction in volume and compaction of the final product tissue, which increases the force required to tear the sample tissue. Given the higher volume of the samples containing cooked lentil flour, one of the reasons for the decrease in the stiffness value in these treatments was their higher volume. The structural changes that occur in the core are related to the interactions between starch and other compounds. In wheat-based baked products, gluten plays the main role, but in gluten-free products, polysaccharide compounds play a more fundamental role in the structure of the cake than protein [48]. Using flour or additives containing high fiber content increases the water holding capacity and swelling of the dough cells during baking [49].

## 3-10-Color parameters of manufactured cakes

Color is one of the most important quality parameters that reflects the type of primary ingredients used in the preparation of the product and the conditions applied for its processing [50]. Due to the use of cheap raw materials (types of starches obtained from plant sources) in the formulation of gluten-free products, these products lack a color that is desirable from the consumer's perspective [51]. The results related to the measurement of the color components of the crust of gluten-free cakes are given in Table 5. The amount of cooked lentil flour present in the formulation caused noticeable color changes in the color parameters of the crust of gluten-free cake samples. An examination of the results obtained for the crust of gluten-free cakes showed that the addition of cooked lentil flour caused a decrease in the values of the lightness index (L*) and yellowness index (b*) and an increase in the redness index (a*). The final color of flour products is the result of complex physicochemical reactions between proteins and carbohydrates during baking. In addition, the gluten-free cake formulation is also an influential factor in the final color of the product. Given the color nature of cooked lentil flour, which is darker than the rice flour used in the formulation, the occurrence of noticeable color changes was largely predictable. Therefore, the reason for the decrease in the brightness of the samples with increasing percentage of cooked lentil be attributed to the darker color of lentil flour compared to rice flour. One of the reactions that influences the formation of the crust color of flour products is non-enzymatic browning. Given the higher protein content of cooked lentil flour compared to rice flour, the intensification of the reaction can also be partly the cause of the color changes in the crust of gluten-free cake samples containing cooked lentil flour compared to the control sample. Regarding a* parameter, which indicates the color spectrum from red to green. Considering the use of cooked lentil flour, a* value moved towards negative values, as expected. This actually indicates that the cake color tends towards green. With an increase in the percentage of cooked lentil flour, the intensity of this green increased, because the color compounds present in cooked lentil flour are added to the general color composition of the cake. These color changes could also be due to the presence of chlorophyll pigments in cooked lentil flour, which contributes to the green and darker color of the gluten-free cake sample. Cooked lentil flour usually has a more yellow or greenish color, so replacing rice flour with green lentil flour increased the b* value in the gluten-free cake samples and the cake became more yellow or greenish in color. These changes were especially significant at higher percentages of cooked lentil flour (50 and 80 percent). Gulhan and Karaca (2023) reported similar results to the present study in their investigation of color parameters of muffin cake samples [52].

**Table 5- The effect of lentil flour percentage on cake color parameters**

| Characteristics | Control | 70R30L | 50R50L | 20R80L |
|---|---|---|---|---|
| $L^*$ | $51.00\pm2.00^a$ | $38.44\pm1.52^b$ | $32.27\pm2.08^c$ | $27.66\pm1.57^d$ |
| $a^*$ | $3.33\pm1.48^d$ | $8.24\pm1.00^c$ | $10.54\pm0.48^b$ | $16.70\pm1.52^a$ |





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| b* | 29.00±1.64[a] | 25.33±1.78[b] | 21.33±1.52[c] | 14.00±1.00[d] |
|---|---|---|---|---|

Different lowercase letters within a row indicate significant differences in %5 level

## 3-11- General acceptance

In the food industry, the acceptance and acceptability of a product by consumers guarantees the production of that product and its continued presence in the consumer market. Therefore, the evaluation of sensory properties plays a fundamental role in selecting the best formulation. In terms of general acceptance, the review of the sensory evaluation results by the evaluators also confirmed that the use of lentil flour cooked up to 30% in the gluten-free cake formulation was able to receive more points from the sensory evaluators, which had no statistically significant difference with the samples containing 50% lentil flour and the control sample (Figure 1). Gulhan and Karaka (2023) also stated, similar to the results of this section, that adding lentil flour up to 30% to the formulation of manufactured muffins did not significantly change the sensory properties of the products from the evaluators' perspective [52].

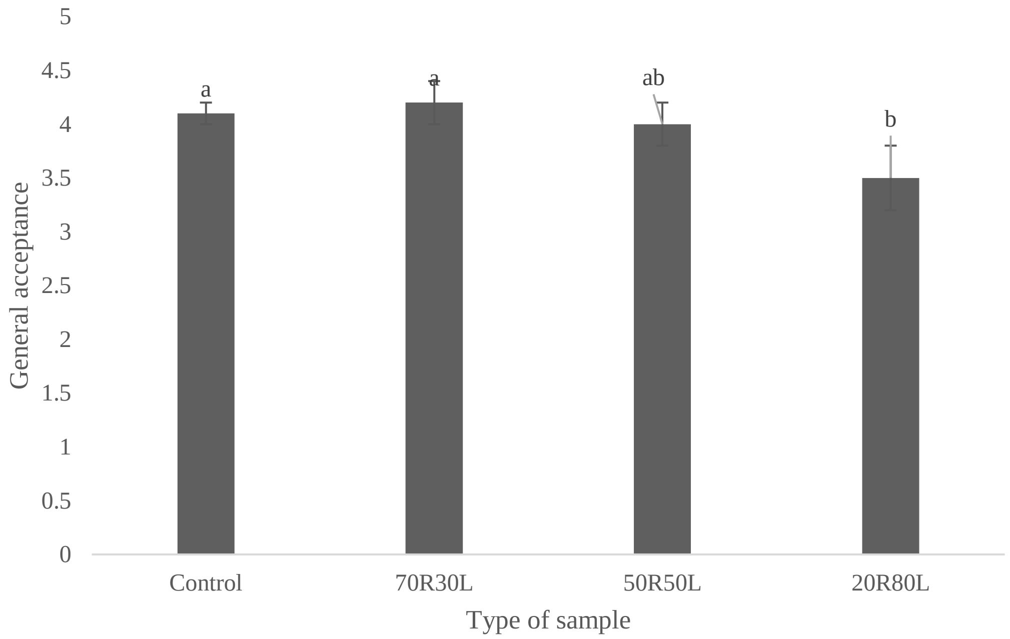


**Figure 1: The effect of the percentage of lentil flour on the general acceptance of gluten-free cakes based on rice flour**

## 4- Conclusion

Regarding the objectives of this study, in relation to the pretreatments performed on lentil seeds, which included soaking and peeling, cooking and roasting, the results obtained showed that cooking and roasting pretreatments (applying wet and dry thermal processes) improved the functional properties of lentil flour in terms of water and oil holding and emulsifying capacity compared to soaking and peeling. After examining the functional properties, cooked lentil flour was selected as the optimal treatment and used in the formulation of gluten-free cakes at different levels. The investigation of the properties of gluten-free cake dough indicated that increasing the percentage of replacing cooked lentil flour at different levels instead of rice flour increased the density and consistency of the dough samples. In terms of nutritional properties, the results showed that replacing cooked lentil flour with rice flour in gluten-free cake formulations can effectively increase the protein content of the final product. The study of technological properties also showed that using up to 50% cooked lentil flour in gluten-free cake formulations can improve the quality properties and general acceptance of the samples.

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مقاله علمی_پژوهشی

# بررسی تأثیر پیش تیمارها و سطوح مختلف جایگزینی آرد دانه عدس بر روی ویژگی‌های فیزیکوشیمیایی و حسی کیک بدون گلوتن بر پایه آرد برنج

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| اطلاعات مقاله | چکیده |
| --- | --- |
| **تاریخ های مقاله :**<br>تاریخ دریافت: ۱٤۰۳/۷/۱۹<br>تاریخ پذیرش: ۱٤۰۳/۹/۲۱<br>**کلمات کلیدی:**<br>آرد دانه عدس،<br>کیک بدون گلوتن،<br>خیساندن- پوست‌گیری،<br>پختن،<br>برشته کردن.<br>DOI: 10.22034/FSCT.22.161.42.<br>* مسئول مکاتبات:<br>m.gharekhani@iau.ac.ir | این مطالعه با هدف ارزیابی اثرات پیش تیمارهای خیساندن- پوست‌گیری، پختن و برشته کردن دانه عدس بر روی ویژگی‌های عملکردی (قابلیت جذب آب و روغن و امولسیون کنندگی) آرد عدس و سپس انتخاب تیمار بهینه و جایگزینی آن با آرد برنج در فرمولاسیون کیک بدون گلوتن و بررسی تأثیر آن بر خواص فیزیکی، کیفی و حسی کیک بدون گلوتن انجام شد. جایگزینی آرد دانه عدس با آرد برنج در فرمولاسیون کیک بدون گلوتن، در سطوح (۳۰، ۵۰ و ۸۰ درصد) انجام شد. بررسی تأثیر پیش‌تیمارهای مختلف نشان داد که آرد عدس پخته شده دارای بالاترین مقدار جذب آب (۲/۰۰ درصد)، جذب روغن (۱/۳۸ درصد) و ظرفیت امولسیون کنندگی (٤٤/٦۰ درصد) بود. بر اساس نتایج به‌دست آمده آرد عدس پخته شده به‌عنوان تیمار بهینه انتخاب و در فرمولاسیون کیک بدون گلوتن مورد استفاده قرار گرفت. نتایج حاکی از آن بود که با افزایش مقدار جایگزینی آرد عدس دانسیته و قوام خمیر، میزان رطوبت، پروتئین و شاخص $a^*$ کیک‌های تولیدی افزایش ولی میزان سفتی و شاخص‌های $L^*$ و $b^*$ کاهش یافت. از نظر پذیرش کلی، بررسی نتایج ارزیابی حسی توسط ارزیاب‌ها نیز موید این امر بود که استفاده از آرد عدس پخته شده تا ۵۰ درصد در فرمولاسیون کیک بدون گلوتن تغییر قابل ملاحظه‌ای از دید ارزیاب‌ها نداشت به‌همین دلیل و با توجه به نتایج این مطالعه می‌توان جایگزین نمودن ۵۰ درصد آرد عدس پخته شده را در فرمولاسیون کیک بدون گلوتن بر پایه آرد برنج پیشنهاد داد. |